second change of hue. Again, after looking at blue for thirty seconds he seeks the third change of hue. The next step is to trace the violet to its limits. After this he works through the spectrum back again, fatiguing the eye with violet before finding the blue, and so on, ending with the determination of the limits of the red. The degree of fatigue is so slight that he is quite unconscious of it.

The seventy cases examined in this way agree as to the number and mean position of the changes of hue, but they may be divided broadly into those whose colour sensations overlap and those whose colour sensations do not overlap, *i.e.*, those who find the changes of tint occur in the same place when working from red to violet as when returning from violet to red.

The first class includes persons both educated and uneducated whose avocations require them to compare colours. The second comprises all who fail with the closer shades of Holmgren's wools. Details are given of some in whom the green and violet are so far extended into each other that they see practically no pure blue, and it is suggested that these, and other differences in the relative intensity and extent of the colour sensations may account for the divergence of opinions among writers on the subject. The paper concludes with an account of five cases of red-blindness.

"On the Connection between the Electrical Properties and the Chemical Composition of different kinds of Glass." By Professor ANDREW GRAY, LL.D., F.R.S., and Professor J. J. DOBBIE, M.A., D.Sc. Received February 7,—Read February 17, 1898.

The experiments and results described in the following paper are a first instalment of work we have undertaken with a view to finally determining, if possible, the circumstances which affect the conductivity and specific inductive capacity of glass. It appeared from some experiments which were carried out by Professor T. Gray and ourselves some years ago,* that it might be of interest to have a number of glasses specially made up with a view to testing some of the conclusions then arrived at.

A result previously obtained by Professor T. Gray had shown that potash and soda lime glasses have a higher conductivity than flint glasses; this result had also been arrived at by Dr. Hopkinson. In particular it seemed desirable to ascertain whether by increasing the amount of lead oxide and diminishing the amount of soda, the conductivity would go on diminishing. We have experienced great

* 'Roy. Soc. Proc.,' No. 231, 1884.

difficulty in getting glasses made according to our own specifications. We endeavoured to make the glasses ourselves, and several experiments were made accordingly, both in the laboratories here and at the Ogwen Tile Works, where a large furnace had been erected for the construction of tiles from slate dust. Some success was achieved, but it was found impossible, without the expenditure of far more time than could be spared, to obtain the glasses in a condition suitable for the experiments we wished to carry out.

Through the kindness, however, of Messrs. Schott & Co., of Jena, and of Messrs. Powell & Sons, Whitefriars, London, we have recently obtained a number of specimens of glass all richer in lead than the specimens formerly available, and, further, in some cases practically free from soda. We have also had made to order by Messrs. Schott specimens of their own glass, used, we believe, chiefly in the construction of thermometers, as well as of a barium crown glass, which have not hitherto, so far as we are aware, been experimented with.

Determination of Conductivity.—The method of experimenting followed was practically the same as that described in the paper already referred to, but its nature may perhaps here be indicated.

Owing to the large percentage of lead oxide in some of the glasses prepared for us by Messrs. Schott, it was found impossible to blow them into flasks, and they were therefore cast into plates; the arrangements therefore required some modification for their case.

The specimens which were in the form of flasks were filled up with mercury to the bottom of the stem (which in most cases was about 8 or 9 inches long), and the flask thus filled was sunk in a bath also containing mercury, so that the mercury was at the same level inside and outside. One terminal of a circuit containing a battery of about thirty secondary cells and a very sensitive galvanometer was connected to the mercury within the flask by a wire passing down the neck, while the other terminal was connected to the mercury in the bath.

The galvanometer was the instrument formerly used and described in 'Roy. Soc. Proc.,' vol. 36, p. 287. It was carefully insulated, as was also the reversing key, and all necessary precautions were taken to make sure that the current passing through the galvanometer was that passing through the walls of the flask between the mercury coatings. Thus it was always verified that no deflection took place when the wire was withdrawn from the flask and placed round the outside of the neck. This test obviated the possibility of the existence of any disturbing film of moisture on the surface of the glass. The bath could be heated to any temperature required in the experiments.

The conductivity was calculated from deflection of the galvano-

meter produced by the current through the glass, the area and thickness of part of the specimen in which the current flowed, as described in the former paper.

In the capacity measurements the plate or flask, as the case might be, was supported as described above. A quadrant electrometer was kept connected to the plates of one of Lord Kelvin's air leydens. This was charged with twelve secondary cells, and therefore to a difference of potential of about 24 volts. After the battery had been removed a reading was taken of the electrometer deflection, and then the specimen was connected for a very short interval of time as a condenser in parallel with the leyden.

This connection was made by means of a myograph pendulum which, when freed, swung over a considerable arc to a catch which prevented it from returning. At its lowest point a metal piece projecting below the bob touched the top of a tongue projecting upwards from a hinge at its lower end, and leaning against the point of an adjustable screw. The connection between the two condensers thus only endured while the three pieces, the screw, tongue, and bob, were in contact. This was only the interval of time required for a pulse of flexure to travel about a centimetre in a bar of steel about half a centimetre thick, and about a centimetre broad. The interval was reckoned as at most about 1/30,000 of a second.

The plates were originally rather over a quarter of an inch thick, and after some observations of capacity had been made on some of them, and it had appeared that their resistance was too great to be measurable, they were cut down on a turning-table used for cutting slates, to a thickness of about 3 mm.; they were then fixed on a bed of pitch, and ground down by hand to a thickness of about 0·24 cm. They were polished and properly cleaned, and then covered on both sides with a dense and thoroughly adherent coating of silver. This was cut away for a space of about half an inch round the edges. Great care was taken to remove every trace of silver, and to make the edge thoroughly clean.

While being experimented on, the glass plate was laid with one coating of silver resting on a plate of copper at the bottom of an iron bath. Another plate of copper was laid on the upper coating of silver, and kept down with a weight, and the connections of the battery circuit, described above, were made with the copper plates. The iron bath was placed within a larger bath partly filled with sand, so that the temperature could be raised by heating the outer bath from below.

The results of the experiments are exhibited in the table which follows. We have there given the density, specific resistance, specific inductive capacity, and chemical composition of each specimen experimented on.

No.	Description of glass.	Density.	Specific resistance (ohms).	Specific inductive capacity.	Chemical Composition.									Total percentage.	Remarks.
					Silica.	Lead oxide.	Ferric oxide and alumina.	Arsenious oxide.	Potassium oxide.	Sodium oxide.	Manganese monoxide				
XXI	Lead potash glass, made by Messrs. Powell and Sons, London.	3·495	Too high to measure, certainly above $18{,}000 \times 10^{10}$ at 130° C.	7·966 at 15° C. 7·630 at 120° C.	50·5	42·14	0·41	...	6·93	trace				99·98	Absorption effects in electrical experiments very marked.
XXII	Lead potash glass, made by Messrs. Schott and Co., Jena.	3·591	Too high to measure, certainly above $35{,}000 \times 10^{10}$ at all temperatures to 135° C.	7·991 at 14° C.	44·5	46·6	trace	0·4	8·0	0·5	trace			100·0	Absorption effect slight.
					Silica.	Boron trioxide.	Alumina.	Manganese monoxide.	Zinc oxide.	Barium oxide	Magnesia.	Potassium oxide.	Sodium oxide.		
XXIII	Barium glass, made by Messrs. Schott and Co. Jena.	3·565	Too high to measure, certainly above $59{,}000 \times 10^{10}$ at all temperatures to 140° C.	8·5. No variation with temperature. No absorption effect.	33·0	12·0	6·0	1·0	...	48·0	...	trace	trace	100·0	This glass showed no trace of polarisation. Trace of arsenious oxide.
XXIV	Zinc soda "Jena glass," made by Messrs. Schott and Co.*	3·493	$596 \cdot 5 \times 10^{10}$ at 43° C. $0 \cdot 200 \times 10^{10}$ at 140° C.	7·54 at 15 C. Conduction too great at high temperatures.	67·6	8·0	trace	0·4	9·0	...	5·0	...	10·0	100·0	Considerable absorption effects.

Dimensions of Specimens.

XXI. Flask.

Internal radius .... 3·741 cm.
External ,, ... 3·522 ,,
Effective surface .... 174·921 sq. cm.

XXII. Plate.

Length of silvered surface 12·81 cm.
Breadth of ditto .... 11·90 ,,
Area........................... 152·439 sq. cm.
Mean thickness .... 0·24 cm.

XXIII. Plate.

Length of silvered surface 18·8 cm.
Breadth of ditto .... 14·31 ,,
Area........................... 269·028 sq. cm.
Mean thickness .... 0·235 cm.

XXIV. Flask.

Effective area .... 209·2 sq. cm.
Mean thickness.............. 0·935 cm.

* Experiments were made with four different flasks of this glass, with results fairly represented by those given in table. The factor of diminution of resistance for a rise of temperature of 20° C. was about one-fifth.

The resistance was taken after five minutes' electrification in each case. The "Jena" glass (XXIV of the table), in both resistance and capacity experiments, showed very considerable effects of dielectric polarisation, which were a very long time in disappearing, though the conducting coatings of the flask were kept short-circuited. The dielectric polarisation of the lead glass made by Messrs. Powell was also considerable.

On the other hand it is very remarkable that the barium glasses XXIII, in the capacity experiments, showed little or no sign of polarisation effects; and we propose to make some further investigations of the physical properties of this glass.

In our previous paper the results obtained with eight different samples of lead glass were compared, and it was shown that the electrical conductivity fell off almost quite regularly as the amount of lead oxide increased, and increased with an increase in the amount of soda. The glass which possessed the highest specific resistance (8400×10^{10} ohms) contained 40·5 per cent. of lead oxide, 7·5 per cent. of potassium oxide, and 2·1 per cent. of sodium oxide. Both of the lead glasses dealt with in this paper contained a still higher percentage of lead oxide, and were almost free from soda, and the electrical resistance was so great as not to be measurable. It is, of course, impossible to say how far this result is due to the increase of lead oxide, and how far to the elimination of soda. With the view of definitely settling this point, Messrs. Powell and Sons have kindly undertaken to prepare for us a glass exactly similar to XXI, but having the potash replaced as nearly as possible by the equivalent amount of soda. It should be noticed that the amount of foreign matter (*i.e.*, of ingredients other than silica, lead oxide, and alkali) present in glasses XXI and XXII is very small, and is less than one-fourth of the amount present in the purest glass previously tested, which was also, it may be mentioned, the glass possessing the highest resistance.

It is noteworthy that the barium glass XXIII has a very high resistance, and in this respect behaves more like lead than lime glasses, which have usually a low resistance. It is impossible, however, in view of the somewhat complicated composition of this glass, to say how far the high resistance is due to the presence of the barium, and how far it may be influenced by other ingredients, especially the boric acid, which was not present in any of the glasses previously examined by ourselves or others.

The "Jena" glass XXIV has a low resistance, as was to be anticipated, from its high percentage of soda and complex composition.

The chemical composition of glass XXI is capable of being expressed with tolerable accuracy by a simple chemical formula, and this is also in accord with previous experience, which pointed to the

conclusion that a glass, which approaches in composition to a definite chemical compound, has a high resistance.

Our knowledge of the chemistry of glasses is still very imperfect, and we cannot say in what way the silica is distributed amongst the bases. We give, therefore, merely the relative number of formula weights of each oxide present, calculated from the analytical numbers, after allowing for the elimination of traces of foreign matter.

Specimen XXI.

After allowing for traces of iron and alumina, the composition of this glass may be expressed by the formula

$$22SiO_2,5PbO,2K_2O,$$

or

$$5(PbO,2SiO_2)+2(K_2O,6SiO_2).$$

	Found.	Calculated.
SiO_2	50·72	50·53
PbO	42·32	42·33
K_2O	6·96	7·13
	100·00	99·99

Specimen XXII.

This glass is essentially a lead potash glass mixed with a very small quantity of a lead soda glass. Allowing for the small quantity of manganese oxide, arsenious oxide, and other impurities present, and eliminating the soda and a corresponding quantity of silica, calculated on the assumption that each formula weight of soda is in combination with three of silica, we obtain as an expression for the composition of the lead potash glass

$$17SiO_2,5PbO,2K_2O.$$

	Found.	Calculated.
SiO_2	44·07	44·11
PbO	47·72	47·82
K_2O	8·19	8·06
	99·98	99·99

Specimen XXIII.

This is a borosilicate of barium and alumina. After allowing for the small quantities of arsenious oxide and manganese oxide which it contains, it has the composition

$$28SiO_2,16BaO,3Al_2O_39B_2O_3.$$

	Found.	Calculated.
SiO_2	33·33	33·35
BaO	48·48	48·20
Al_2O_3............	6·06	6·02
B_2O_3............	12·12	12·40
	99·99	99·97

Specimen XXIV.

The "Jena" glass is essentially a borosilicate of zinc, soda, and magnesia, containing

$$20SiO_2,2ZnO,2MgO,3Na_2O,2B_2O_3.$$

	Found.	Calculated.
SiO_2	67·87	68·05
ZnO............	9·03	9·11
Na_2O............	10·04	10·46
MgO............	5·02	4·50
B_2O_3............	8·03	7·87
	99·99	99·99

"On the Magnetic Deformation of Nickel." By E. TAYLOR JONES, D.Sc. Communicated by Professor ANDREW GRAY, F.R.S. Received February 8,—Read February 17, 1898.

On a former occasion a paper was communicated to the Royal Society* containing an account of some measurements of the magnetic contraction of a nickel wire, and a comparison of these with the values deduced from Kirchhoff's theory. It was there shown that the most important term in the calculated value of the elongation of a long wire of soft magnetic metal is represented by $\frac{1}{2}H(\delta I/\delta P)$, where H is the magnetising field and δI the increase of magnetisation produced by a small increase of longitudinal tension δP per unit area. The results showed that the observed contraction in nickel was much greater than the calculated value. It was then sought to establish an empirical equation which might represent the observed effects, and it was found that the difference between the observed and calculated contraction was approximately proportional to the fourth power of the magnetisation.

It was suggested to me at the time that this result should be tested by repeating the experiments under different conditions in order to find out whether it was generally true.

* 'Phil. Trans.,' A, vol. 189 (1897), p. 189.